TECHNICAL PROPOSAL TO NATIONAL COOPERATIVE HIGHWAY RESEARCH BOARD

FROM

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TRENTON, NEW JERSEY

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N C H R P PROJECT NUMBER 6-10

DEVELOP IMPROVED SNOW REMOVAL AND ICE CONTROL TECHNIQUES AT INTERCHANGES

A B S T R A C T

In order to develop improved snow removal and ice control techniques at interchanges, a study should be made of a more economical heated pavement system. Present snow melting systems, although very effective, are limited by high operating costs. An experimental study of inexpensive sources of heat, such as solar heat, air heat and ground heat, may make the widespread use of heated roadways more feasible.

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I -RESEARCH PROBLEM STATEMENT

The variety of geometrical shapes of interchange ramps, with associated structures, and their urban or rural locations invariably creates problems with respect to optimum snow removal and ice control techniques in the interchange areas. Furthermore, alternate freezing and thawing of plowed or unplowed snow across superelevated ramps contributes to problems in snow and ice control. Drifting may further aggrevate this problem. Improved snow removal and ice control techniques in interchange areas are vital to the safety of highway traffic.

II-RESEARCH PLAN

The ideal solution for the control of snow and ice at interchanges is the use of a heated pavement which is capable of melting any snow and ice forming on the roadway. The use of a heated roadway essentially eliminates all problems associated with conventional snow and ice control techniques, such as limited snow storage areas and the usual time lag between formation of snow or ice on the roadway and plowing, salting and sanding operations. The usual problems of reduced traffic volume and hazardous driving conditions are also eliminated.

The major obstacle presently limiting the use of heated roadways is the high operating cost of such an installation. Present installations have, therefore, been restricted to locations where conventional means of snow and ice control have proved inadequate, thus justifying the higher costs of a heated pavement. (See Appendix)

The two types of heated pavement systems currently in use are:

1. a network of pipes embedded in the roadway, through which a hot fluid is circulated. The heat for this system is usually supplied by a conventional gas or oil fired boiler. (A unique exception to this is the use of natural hot springs in Klamath Falls, Oregon.) Although this type of system operates satisfactorily, it needs to be installed where a supply of hot water is available.

2. a grid of electric resistance wires embedded in the pavement. This system is attractive in that little auxiliary equipment is needed, as in the embedded pipe system. However, due to high demand charges on electricity, it is often costly to operate.

Since the high operating costs present the major drawback to a heated pavement system, a study should be made of less expensive sources of heat.

The proposed research program is designed to evaluate experimentally the following sources of heat:

I Solar Heat

II Ground Heat

III Air Heat

contractor elected to use this glassphalt. Of these six projects, three contractors took advantage of the alternate design. The Department intends to continue the glassphalt alternate program for all asphalt construction projects awarded in the near future. It is believed that the glassphalt product will be a competitive alternate even without the Department's incentives.

MARKET FORCES

It is the intention of the NJDOT to allow market forces to determine whether a virgin product or a recycled product would be used in a given circumstance. This approach has been quite effective in identifying the most economical material to perform a job. An example of this factor is the use of recycled concrete aggregate (RCA) as an alternate for dense graded aggregate base course (DGABC). Once it was determined that the performance of RCA was equivalent to virgin DGABC, the specification was rewritten permitting the use of RCA as an alternative. Over the five or so years that this specification has been in operation market forces have led to the use of approximately 10 to 15% RCA as a substitute for DGABC applications each year. The decision as to which material was used was made exclusively by the contractor and presumably was based on cost. The concept of market forces controlling the use of recycled materials is fundamental to the Department's recycling program.

I. Solar Heat

A. Collection - Heat incident upon the surface of a roadway will be collected by circulating a fluid through a network of pipes embedded in the roadway. This operation will be primarily conducted during the warm summer months. The heat will be stored and later used during the winter for snow melting by use of the same pipe network.

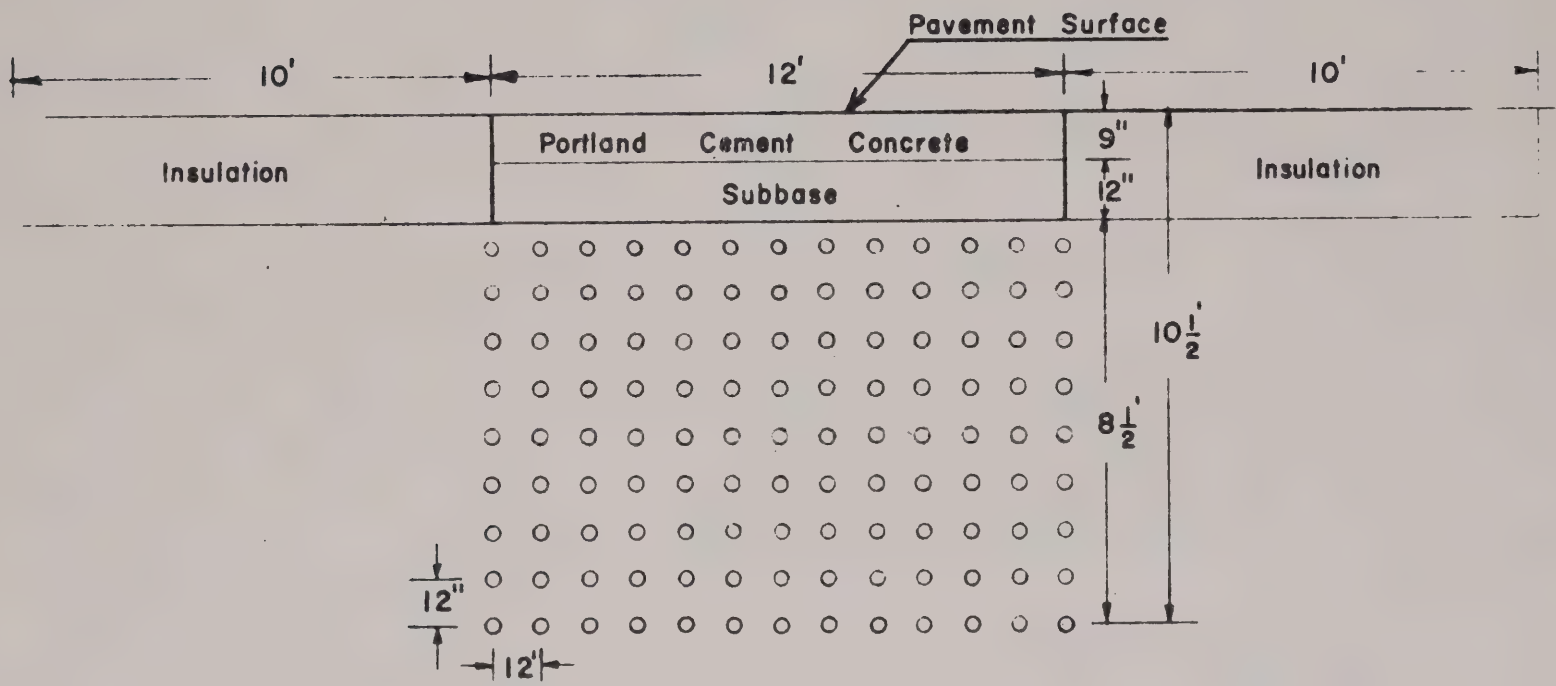
B. Storage - Heat will be stored in the ground, either below or adjacent to the roadway. Heat will be transferred to the ground by means of a heat exchanger comprised of a grid of pipes spaced at one to three foot centers. These pipes will be buried in layers down to a total depth of approximately ten feet. (Fig. 1 & 2) During the summer months, or whenever the temperature of the pavement surface is greater than the ground temperature, fluid from the pavement heating pipes will be pumped through the heat exchanger, thus increasing the temperature of the ground. Later, during periods of snow, the cycle will be reversed and heat will be pumped back through the pipes in the pavement.

II. Ground Heat

A. Collection

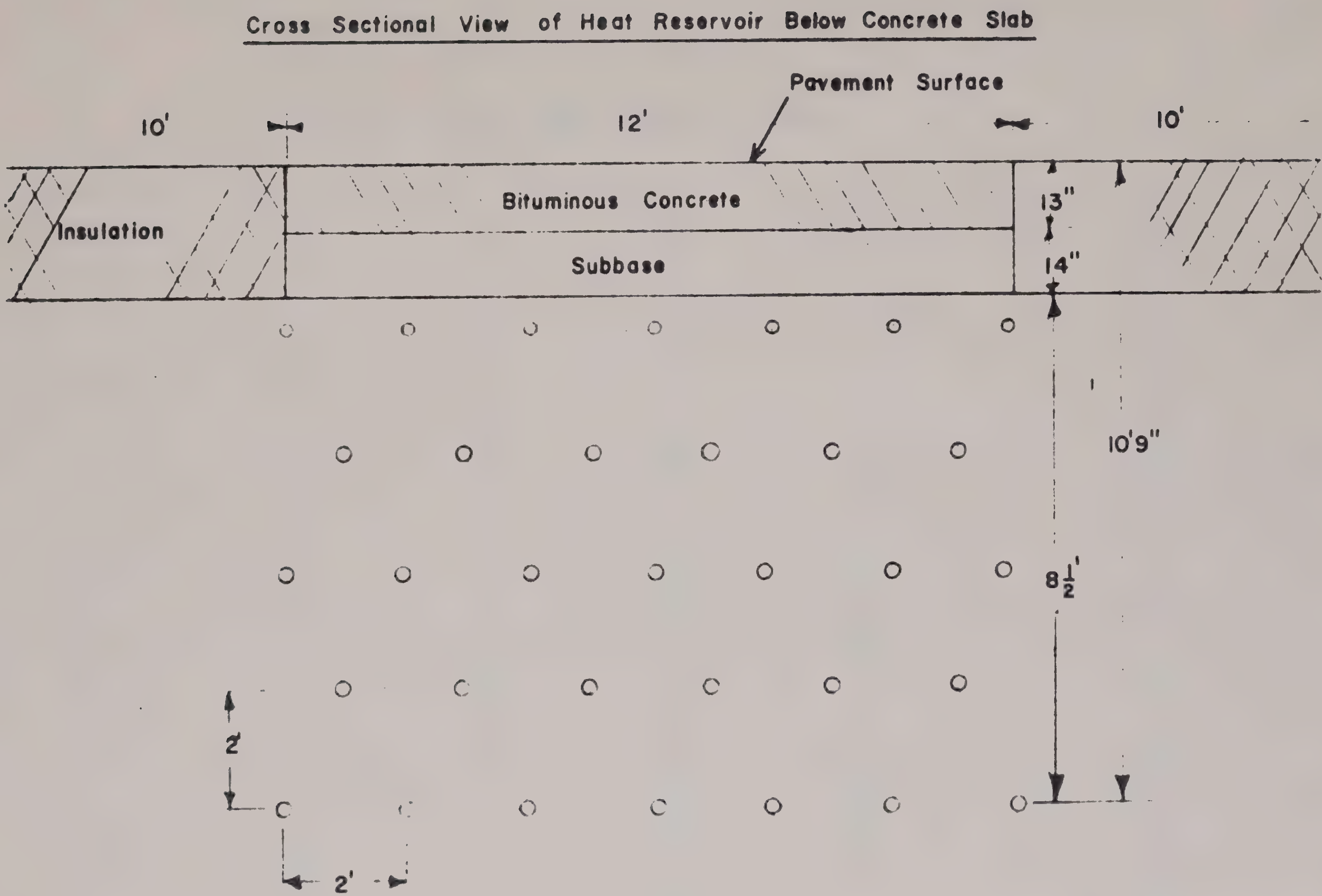
1. A length of pipe will be buried in the ground at a depth of ten to twenty feet, where the temperature of the earth is constant (55°F in New Jersey). The heat from the ground will then be pumped to the pavement heating pipes by means of a heat transfer fluid. (Fig. 3)

Cross Sectional View of Heat Reservoir Below Concrete Slab



NOTE: INSULATION WILL BE USED IN TEST TO DETERMINE EFFECT UPON HEAT RETENTION IN RESERVOIR

Figure 1



Cross Sectional View of Heat Reservoir Below Concrete Slab
Pavement Surface
10'
12'
10'
Insulation
Bituminous Concrete
Subbase
13"
14"
10'9"
8 1/2'
2'
2'

Figure 2

Experimental Ground Heat Collection System

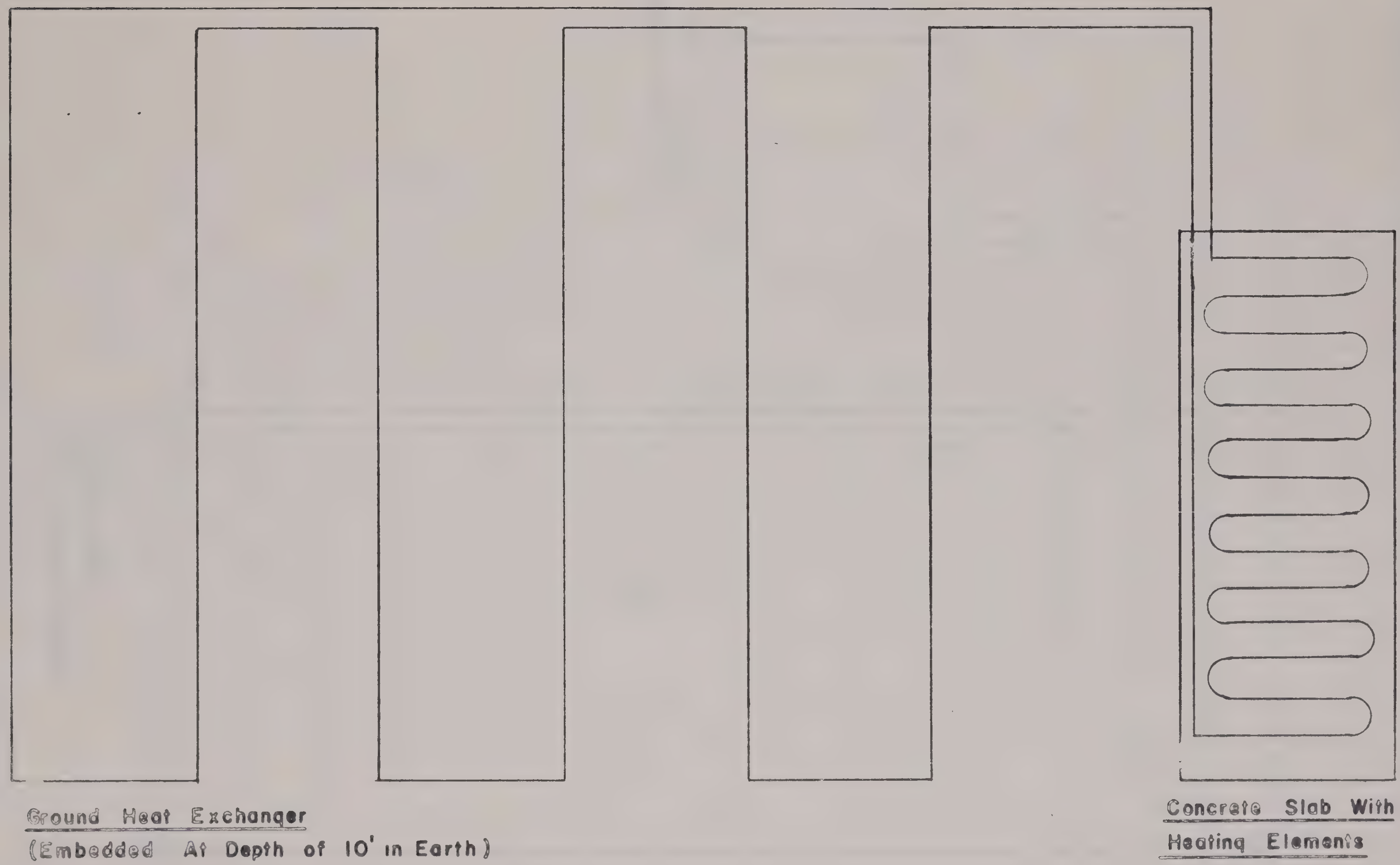


Figure 3

Ground Heat Collection And Storage Utilizing Heat of Fusion

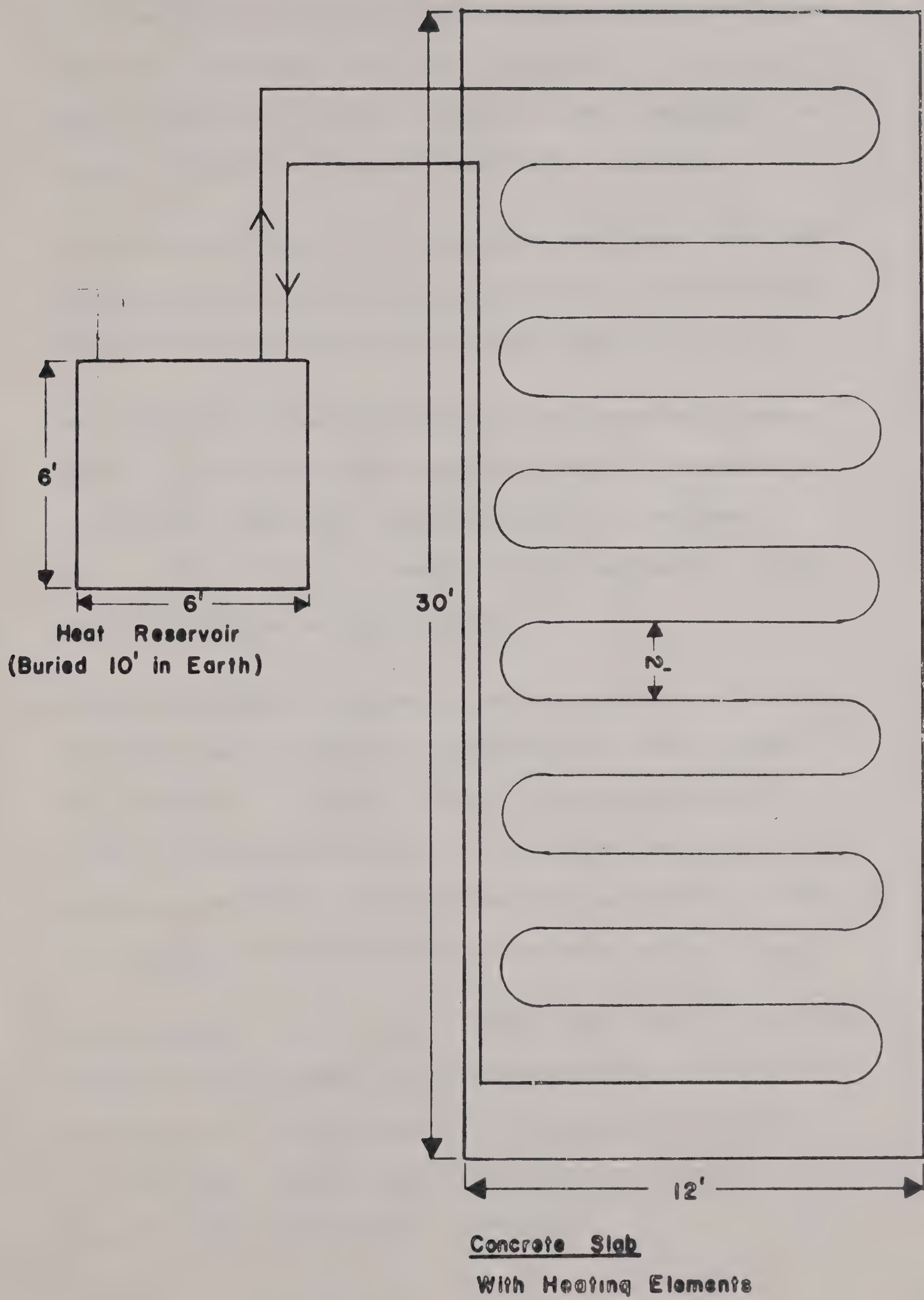


Figure 4

2. A more desirable method of utilizing ground heat may be through the use of a commercial heat pump. By design, a heat pump is able to extract heat from a source at a lower temperature and deliver this heat at a higher, more useful temperature.

   By virtue of the fact that a heat pump just "pumps" heat from a lower temperature to a higher temperature, it has an output energy several times that of the input electrical energy.

   Heat will be extracted from the ground as described in paragraph (1), however, by use of the heat pump, the temperature of the fluid supplied to the heating pipes in the pavement will be much higher. In general, higher temperatures are more desirable for snow melting purposes.

3. A third possibility is to collect and store heat by utilizing the latent heat of fusion of some chemical. Such a system will consist of a container, filled with some appropriate chemical, buried in the ground. The chemical (melting point approximately 45^{o}F) in the container will be kept in a liquid state by heat diffusion from the surrounding earth. (Fig. 4)

   During periods of use, a heat transfer fluid will be circulated through a heat exchanger in the storage container and then to heating pipes in the pavement. After heating the pavement, the cooled heat transfer fluid is pumped back through the heat exchanger in the storage container.

When the temperature of the storage chemical drops below $45^{o}F$ it will freeze, thus releasing its latent heat of fusion. Later, the frozen storage chemical will be re-melted by heat from the surrounding earth.

This system offers the advantage that heat can be gradually stored between periods of snow but quickly released when needed.

III. Air Heat

A. Collection - Heat will be extracted from the air during the winter months by the use of a commercial heat pump.

In this case air will be the source of heat rather than the ground as was previously suggested. The use of the air as a heat source eliminates the cost of burying pipes in the ground.

The heat extracted from the air may be either stored or used directly. (Fig.5)

B. Storage

1. Ground storage - Heat from the air heat pump will be stored in the earth below the roadway. (Fig.6) The heat from the air will be transferred to the ground by means of a heat exchanger buried beneath the roadway. This method is the same as the ground storage of solar heat.

Use of an air heat pump will allow heat to be collected and stored both winter and summer.

2. Chemical storage - Heat supplied by the air heat pump will be stored in a chemical reservoir, utilizing the latent heat of fusion. (Fig. 7) This type of storage is discussed under the chemical storage of ground heat. Use of the air heat pump will permit chemical heat storage at temperatures above 45°F as required when using ground heat.

DIRECT HEAT PUMP HEATING

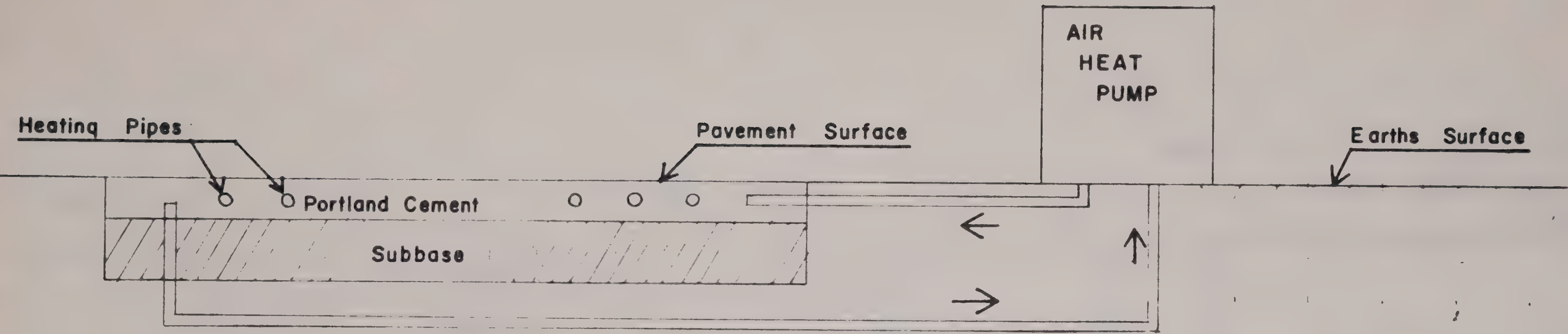


Figure 5

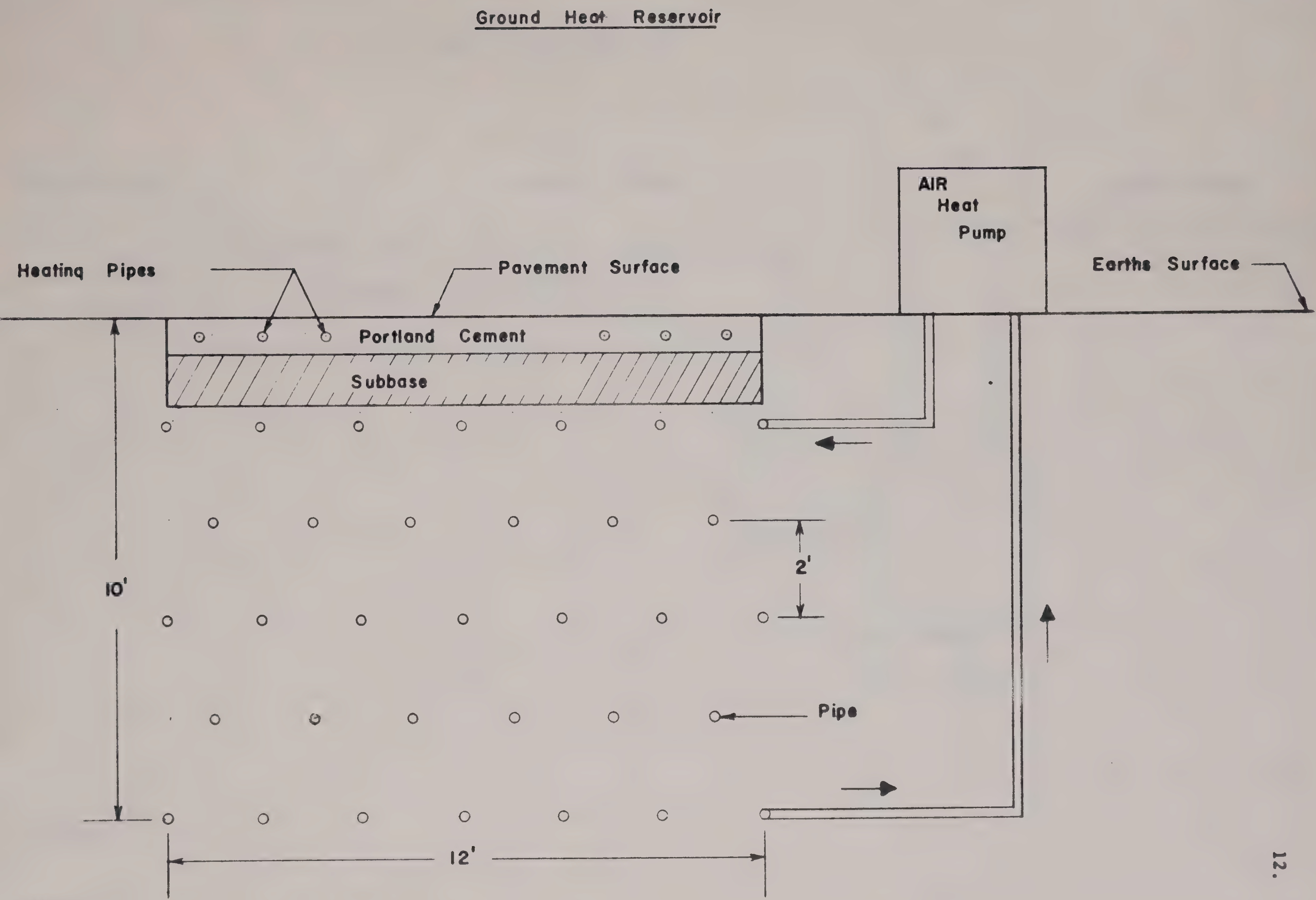
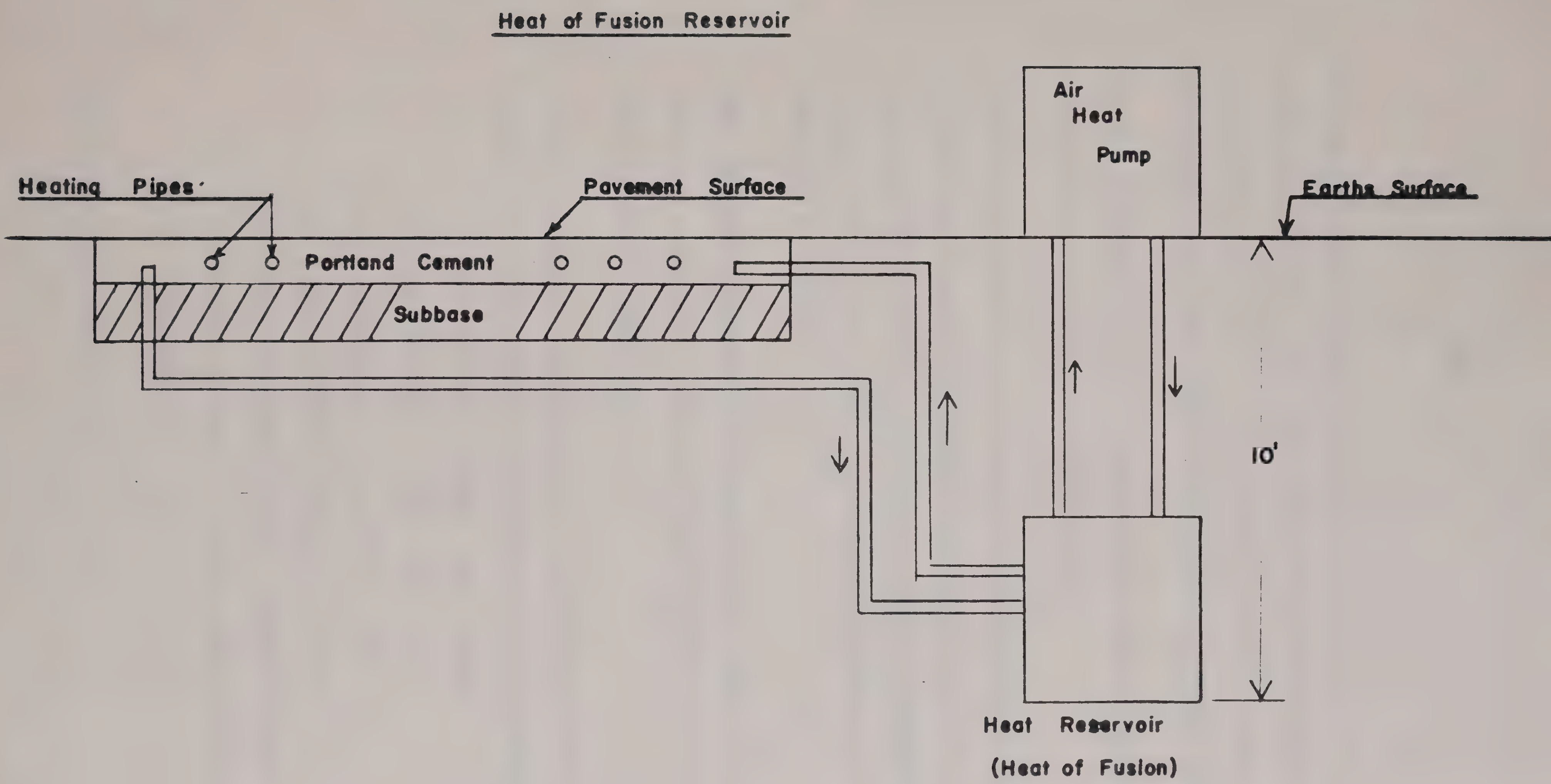

Ground Heat Reservoir
AIR
Heat
Pump
Heating Pipes
Pavement Surface
Earths Surface
Portland Cement
Subbase
2'
10'
Pipe
12'

Figure 6



Heat of Fusion Reservoir
Air Heat Pump
Heating Pipes
Pavement Surface
Earths Surface
Portland Cement
Subbase
10'
Heat Reservoir
(Heat of Fusion)

Figure 7

The proposed experimental pavement heating system will be designed to incorporate all heat sources and heat storage systems with a minimum of duplication and expense. It will then be possible to test each system individually or various combinations in order to obtain optimum results.

A major consideration of any snow melting system using embedded pipes is the design feature of the heating pipes.

A successful system must take into account such variables as the spacing of the pipes, diameter of the pipes and depth of embedment. These features are especially important in this system where the temperature of the heat transfer fluid is below 100°F. (Conventional systems use temperatures from 100°F to 200°F.)

Other features influencing the economy of the system are the use of Bituminous Concrete vs. Portland Cement Concrete and the use of plastic pipe vs. iron or copper pipe.

To better evaluate these factors, the experimental roadway will contain various pipe systems designed to investigate the following variables:

a. Pipe material - copper, iron, plastic

b. Pipe spacing - 6", 12", 18", 24"

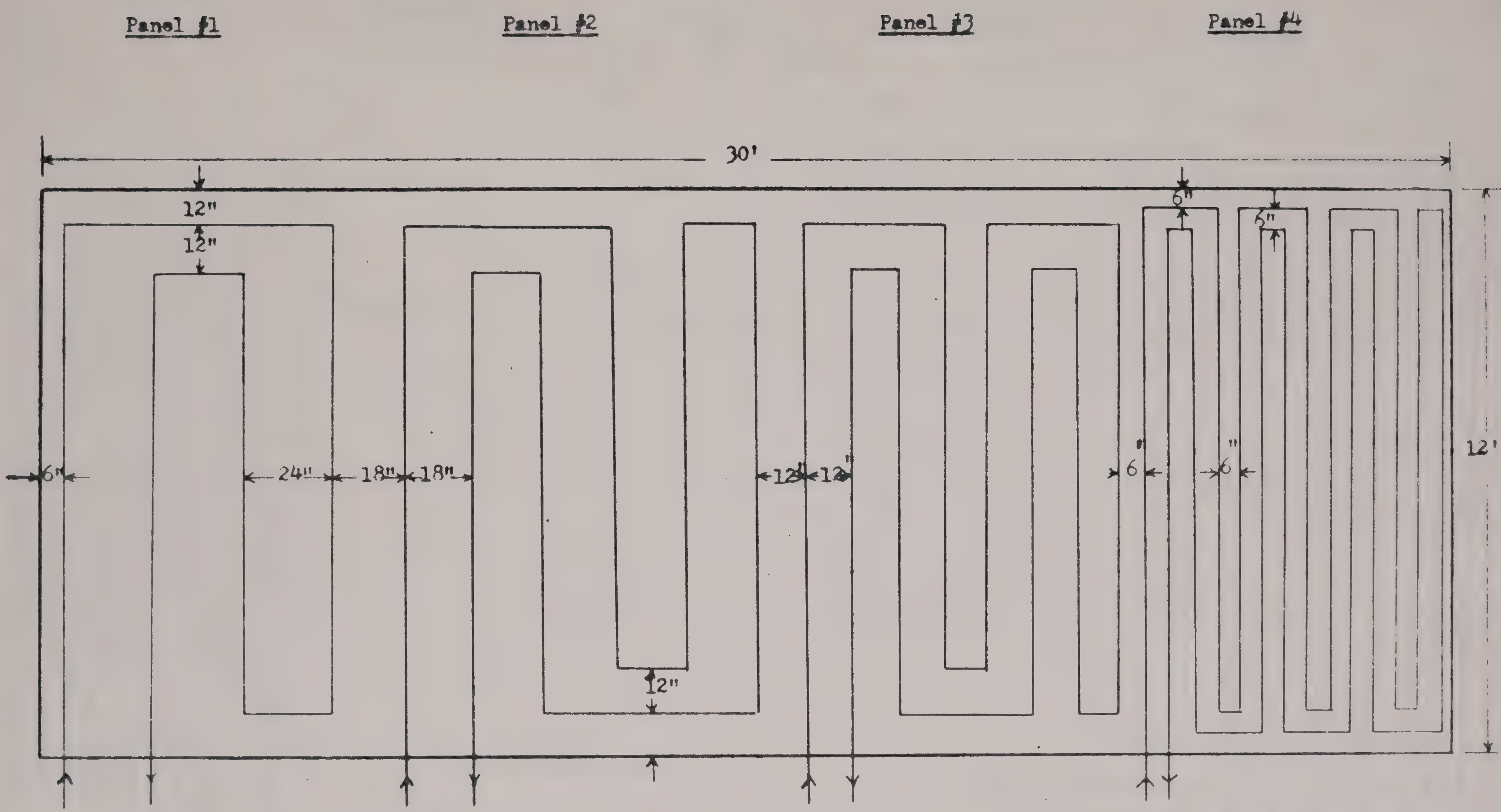
c. Pipe diameter - ½", 3/4", 1", 1½", 2"

d. Depth of embedment of pipe - 2" to 4"

e. Geometric layout of pipes - grid or sinuous

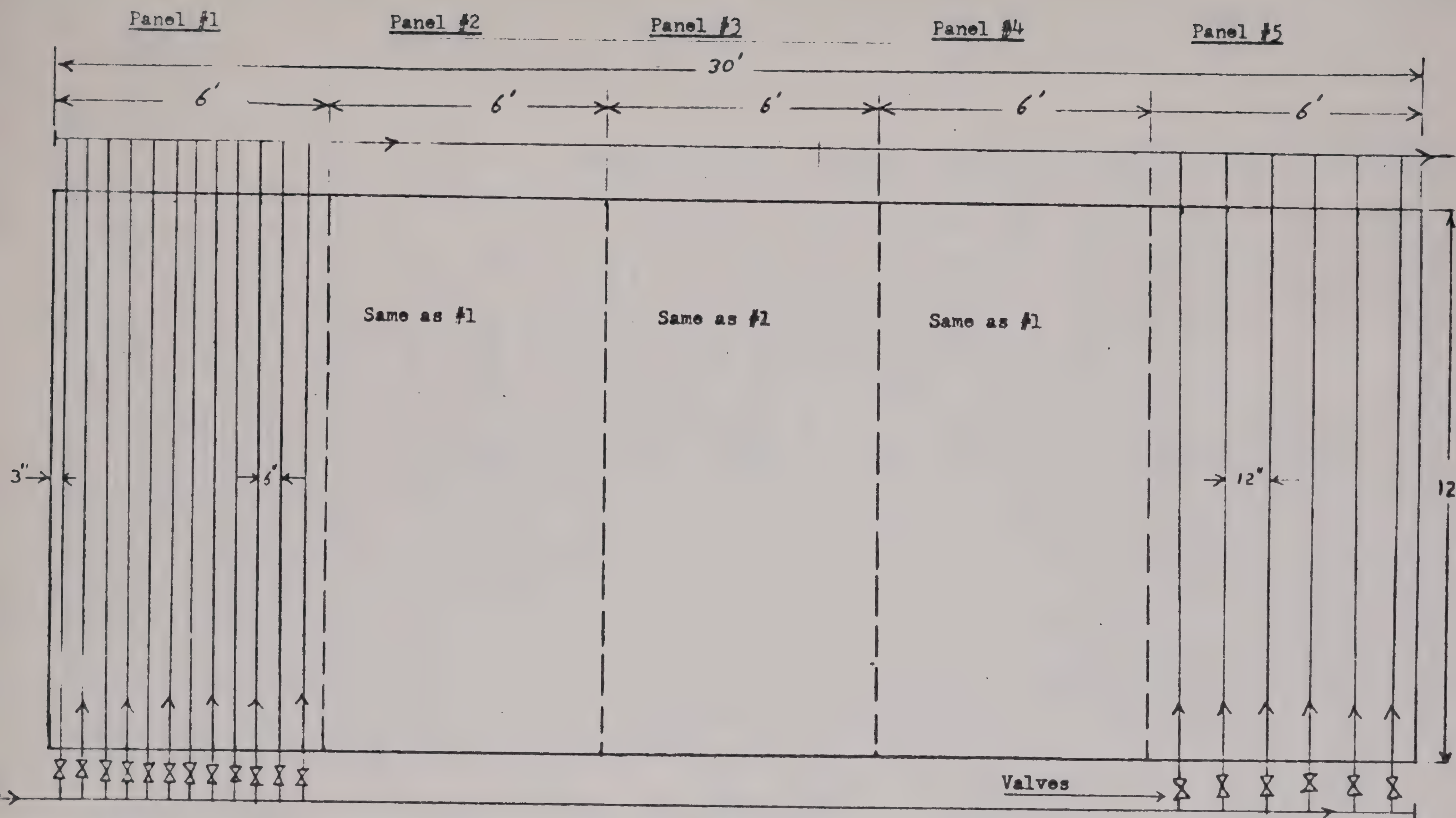
f. Pavement material - Portland cement concrete or bituminous concrete

See Figures 8, 9, 10, 11, 12



Panel #1	Panel #2	Panel #3	Panel #4
Pipe: Iron	Pipe: Iron	Pipe: Iron	Pipe: Iron
Dia.: 1"	Dia.: 1"	Dia.: 1"	Dia.: 1"
Spacing: 24"	Spacing: 18"	Spacing: 12"	Spacing: 6"

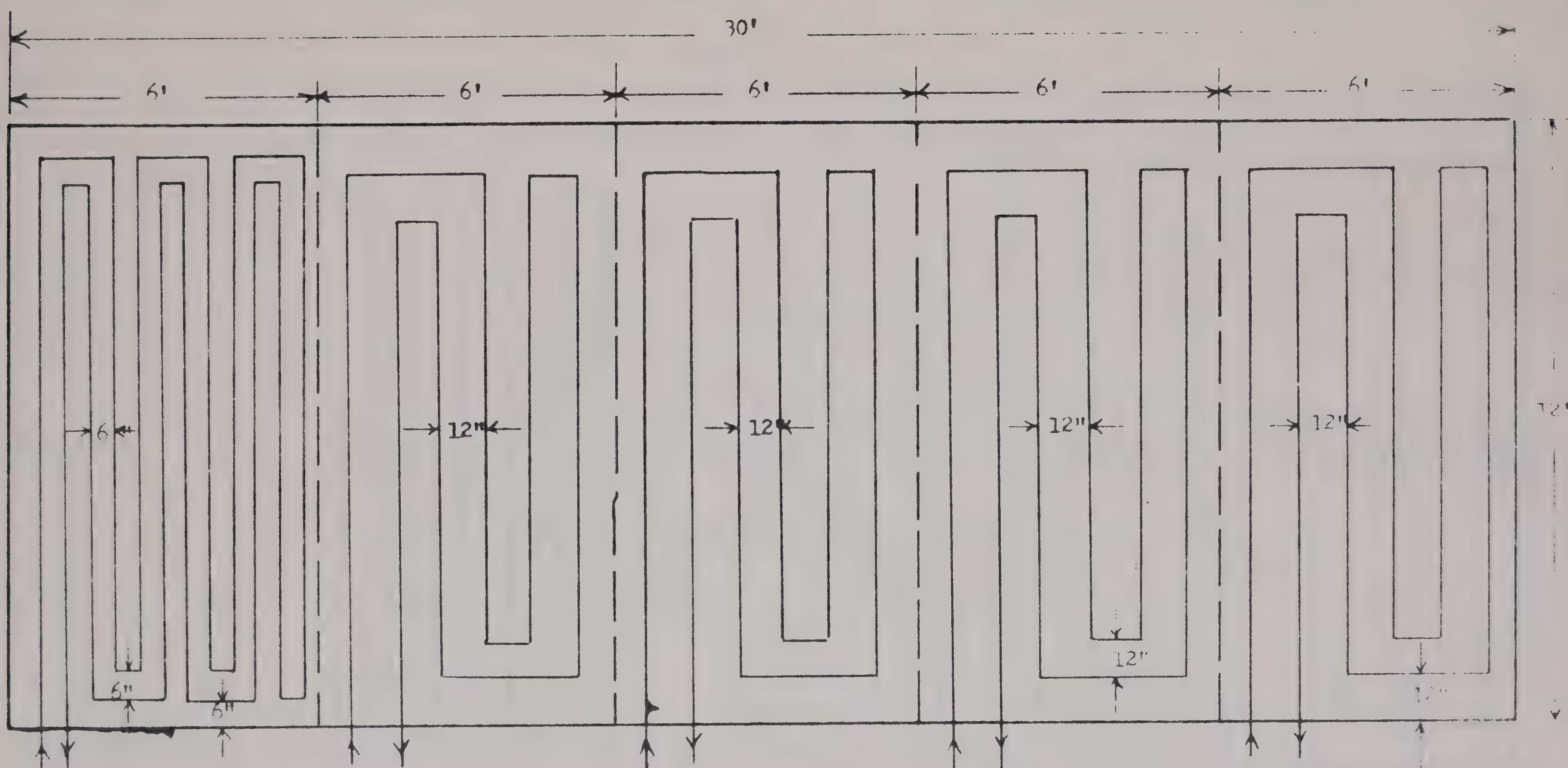
Figure 8 SLAB MATERIAL - PORTLAND CEMENT CONCRETE AND BITUMINOUS CONCRETE



Panel #1	Panel #2	Panel #3	Panel #4	Panel #5
Pipe: Iron	Pipe: Iron	Pipe: Iron	Pipe: Iron	Pipe: Iron
Dia.: 3/4"	Dia.: 1"	Dia.: $1\frac{1}{4}$"	Dia.: $1\frac{1}{2}$"	Dia.: 2"
Spacing: 6"	Spacing: 6"	Spacing: 6"	Spacing: 6"	Spacing: 12"

Figure 9

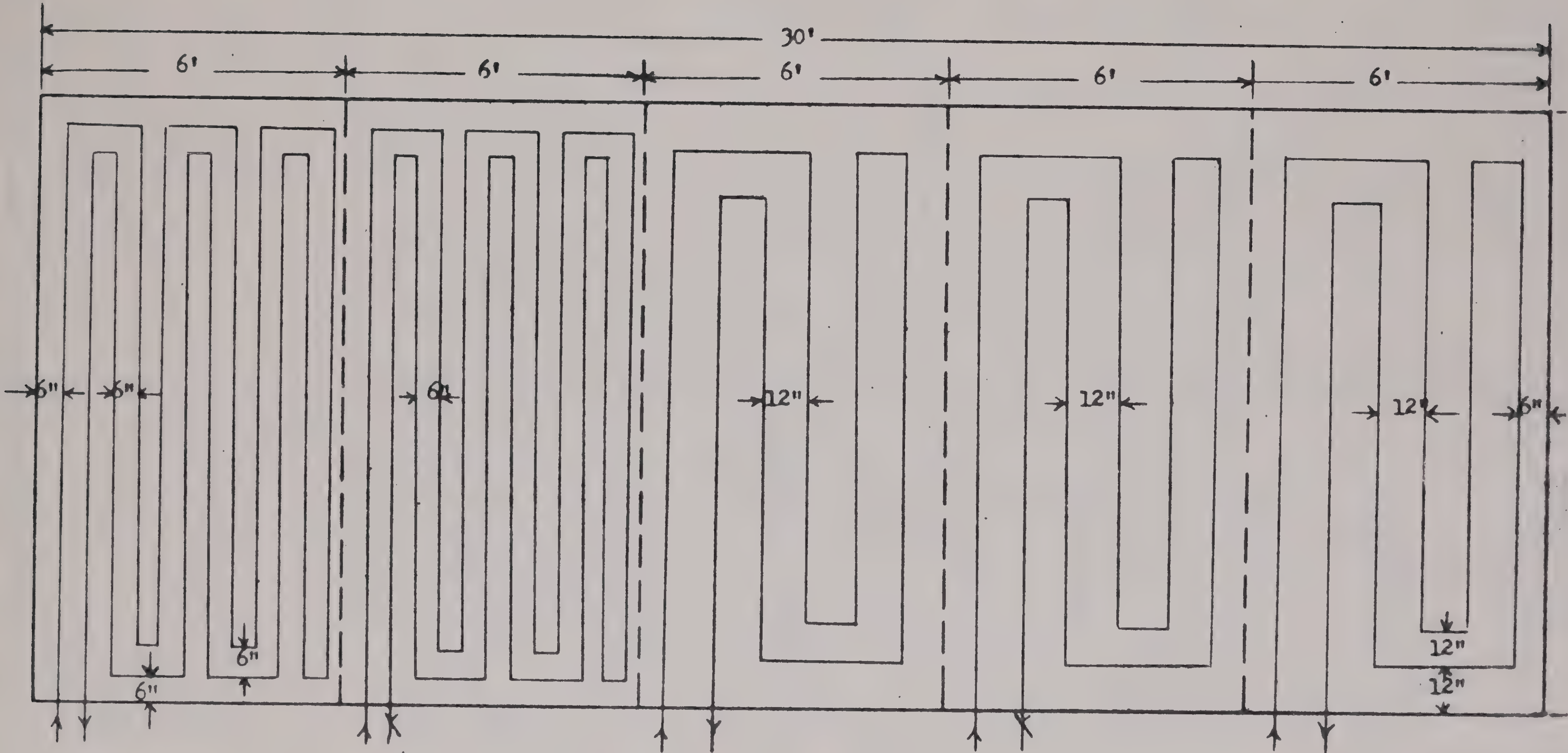
SLAB MATERIAL - PORTLAND CEMENT CONCRETE AND BITUMINOUS CONCRETE



Panel #1	Panel #2	Panel #3	Panel #4	Panel #5
Pipe: Plastic	Pipe: Plastic	Pipe: Plastic	Pipe: Copper	Pipe: Copper
Dia.: 1"	Dia.: 1"	Dia.: 1¼"	Dia.: 1¼"	Dia.: [illegible]
Spacing: 6"	Spacing: 12"	Spacing: 12"	Spacing: 12"	Spacing: [illegible]

Figure 10 SLAB MATERIAL - PORTLAND CEMENT [illegible]

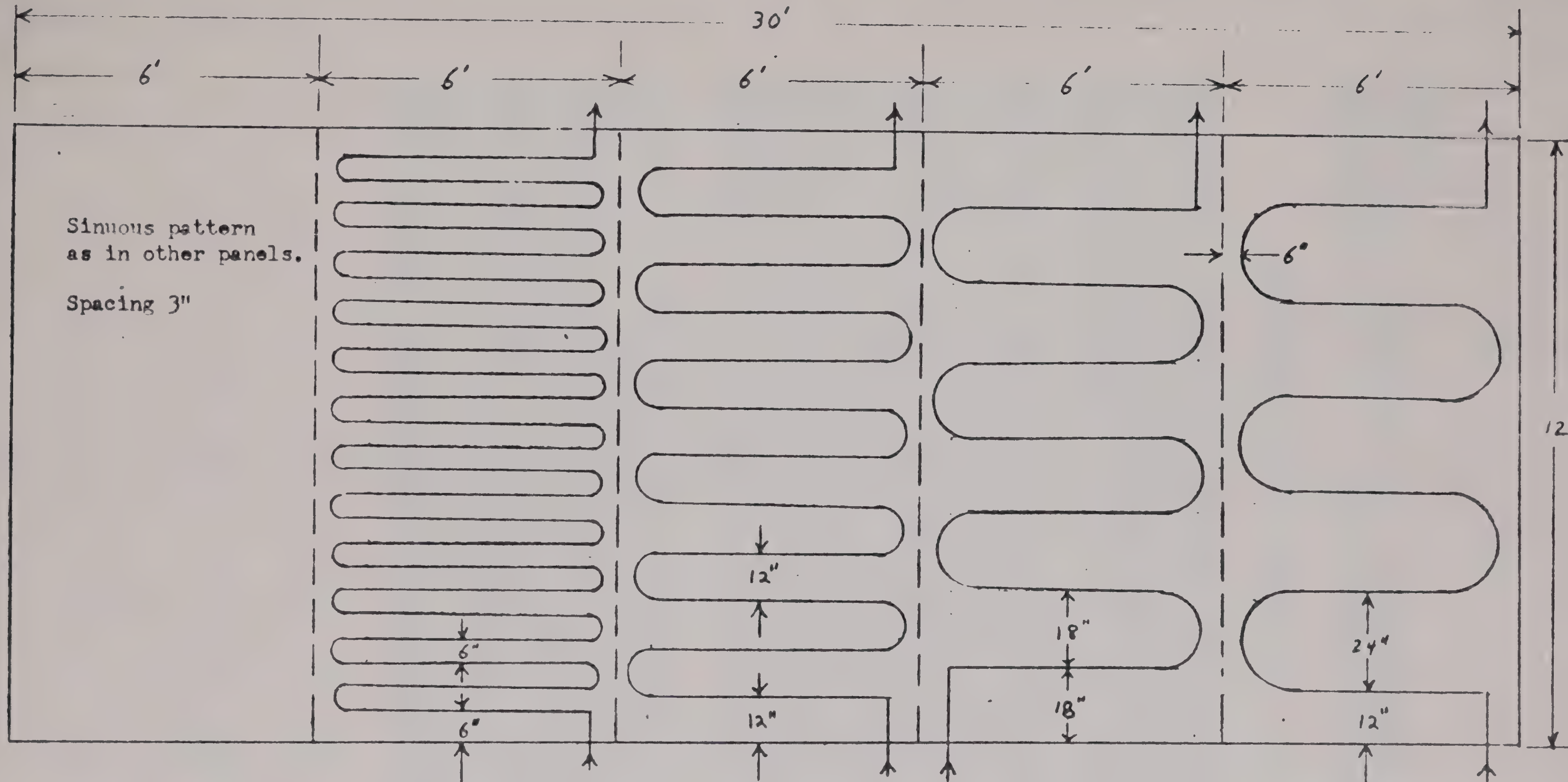
Panel #1 Panel #2 Panel #3 Panel #4 Panel #5



Panel #1	Panel #2	Panel #3	Panel #4	Panel #5
Pipe: Plastic	Pipe: Copper	Pipe: Copper	Pipe: Plastic	Pipe: Plastic
Dia.: 1"	Dia.: 1"	Dia.: 1"	Dia.: 1"	Dia.: 1¼"
Spacing: 6"	Spacing: 6"	Spacing: 12"	Spacing: 12"	Spacing: 12"

Figure 11 SLAB MATERIAL - BITUMINOUS CONCRETE

Panel #1 Panel #2 Panel #3 Panel #4 Panel #5



Pipe: Copper	Pipe: Copper	Pipe: Copper	Pipe: Copper	Pipe: Copper
Dia.: ½"	Dia.: 1"	Dia.: 1"	Dia.: 1½"	Dia.: 2"
Spacing: 3"	Spacing: 6"	Spacing: 12"	Spacing: 18"	Spacing: 24"

Figure 12 SLAB MATERIAL - PORTLAND CEMENT CONCRETE

III-PERSONNEL

The Principal Investigator bearing scientific responsibility for the proposed project will be W. R. Bellis, Director, Division of Research and Evaluation.

1035 Parkway Avenue, Trenton, N.J.
609-292-5700

After graduating from Rutgers in 1926 with a B.S. degree in Civil Engineering, Mr. Bellis worked for a short time with the Concrete Steel Company in New York City and with the Port of New York Authority. With the Port of New York Authority, he was assigned to the location surveys for the Goethals Bridge between Bayonne, New Jersey and Port Richmond, Staten Island, New York City.

He then started work with the New Jersey State Highway Department in March of 1927 as a Junior Engineer, where he has worked continually progressing to the position of Director of the Division of Research and Evaluation. During World War II, he served with the Armed Forces as a Highway Traffic Engineer, with an assimilated rank of Lieutenant Colonel, in the French and German combat areas for nine months, while on leave from the Highway Department. He has been instrumental in the design of numerous unique channelized intersections and has played an important part in many of the achievements for which the New Jersey State Highway Department is justly noted throughout the world. He was a major factor in the selection of the alignment location for the New Jersey Turnpike (then Routes 100 and 300) and for the Garden State Parkway (then Route 4). He also was responsibile for traffic volume estimates used in the design of these roads.

Mr. Bellis is listed in Marquis Who's Who in the East; he is a member of the Institute of Traffic Engineers and of the Engineers Club of Trenton and is a licensed Professional Engineer in New Jersey. He has served as the Chairman of a Committee on Medians in the Institute of Traffic Engineers; he has served on the Committee on Traffic for the American Association of State Highway Officials; and with the Highway Research Board has served on the Committees of Highway Capacity, Channelization and Operational Effects of Geometrics.

He served on the faculty of Columbia University of New York City as a lecturer in traffic engineering for six years, and has lectured at Rutgers and other schools.

Other Research Principals

Dr. Richard E. Borup, Ph.D.
1035 Parkway Avenue
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609-292-5730

Dr. Borup obtained his B.S. degree from the University of Minnesota in 1937. After teaching high school chemistry, physics, and mathematics for two years, he attended the University of Michigan where he received his M.S. degree in 1940. He earned his Doctorate at New York University in 1951. He performed post doctoral research at Balliol College, Oxford University, Oxford, England, and has traveled extensively throughout all of the free countries of Western Europe.

His industrial experience covers about 20 years in the field of petroleum, which includes exploration and production, refinery operations, laboratory control, and research and development at the lower and middle management levels. He has published several technical papers and has shared in several patents which have been issued to previous employers.

He is a vereran of World War II, having served with the U.S. Navy in both the Atlantic and Pacific theatres of operation. He holds the rank of Commander and is currently active in the Research Reserve Program under the cognizance of the Office of Naval Research.

He has been a member of the American Chemical Society, American Association of the Advancement of Science, the American Petroleum Institute, American Society of Testing and Materials, the Institute of Radio Engineers, and is a Fellow of the American Institute of Chemists. He holds scholastic and academic honors including Phi Lambda Upsilon and the Society of Sigma Xi.

Dr. Borup came with the New Jersey Department of Transportation as Supervising Engineer of the Bureau of Electronics and Scientific Aids in the Division of Research and Evaluation in June of 1965 after serving a year with the State of Alaska Highway Department, during which time he also taught at the University of Alaska.

His publications and patents are:

1. "Polarographic Determination of Tetracthyl Lead in Gasoline" Proc. A.S.T.M., Vol. 47, 1947.

   A patent covering a portion of the apparatus developed for use in this procedure was issued to the Texas Company, (Texas).

2. "Gravimetric Determination of Zinc Utilizing the Radioisotope Zn^{65}" Anal. Chem. Vol. 25, 1953.

   Ph.D. Thesis - in partial fulfillment of the requirements for the degree of Doctor of Philosophy at New York University, granted in June 1951.

3. "Conductometric Determination of Salt in Crude Oils"

   Presented at the 28th Midyear Meeting of American Petroleum Institute's Division of Refining, Benjamin Franklin Hotel, Phila., Pa., May 15, 1963, and published by the American Petroleum Institute.

   A patent covering the petroleum refinery process version of the instrument developed for this procedure was issued to the Cities Service Company.

4. "X-Ray Spectrographic Procedure for the Determination Calcium, Barium, Zinc and Lead in Hydrocarbon" Anal. Chem. Vol. 36, 1964.

Frank Winters
1035 Parkway Avenue
Trenton, N.J. 08625

609-292-5731

Mr. Winters started with the Division of Research and Evaluation in November 1966 as an Assistant Engineer in the Bureau of Electronics and Scientific Aids.

He graduated from Villanova University in June, 1965, with a B.S. Degree in Physics, and spent the following year doing graduate work with the Physics Department at Oregon State University.

Mr. Winters has had two years experience in the Department of Biochemistry at Jefferson Medical College and has also worked in the Nuclear Physics Research Laboratory at Villanova University. While at Oregon State University he was an instructor in the Modern Physics Laboratory.

Publications

"Loudness of Sound in Automobiles" - Villanova Engineer, May, 1965

IV-Equipment & Facilities

The proposed experimental installation will be located on land owned by the New Jersey Department of Transportation in Trenton, N.J.

All facilities, such as laboratories and machine shops, belonging to the New Jersey Department of Transportation will be available for use.

V - BUDGET

Salaries	
Director - 1 man month	$ 1,500
Supervisor - 1 man month	1,100
Assistant Engineer - 19 man months	11,000
Capital Equipment	
Heat pumps	5,000
Instruments	500
Materials & Service	
Construction of Test Pavement & associated piping	30,000
Travel	500
Reports	400
Total	$50,000

APPENDIX

VI -Supporting Information

Listed here are several locations where heated pavement installations have solved snow and ice control problems.

New Jersey

1. During October 1961, electric heating cables for snow removal and ice control were installed in connection with a bituminous concrete resurfacing operation at the Route 1 & 9 approach to the Passaic River Bridge in Newark, N.J. The cables were installed in an 840-foot length of two lanes of the bridge approach roadway. This approach ascends at a three percent grade and was the scene of major traffic delays during the heavy snowstorms of the previous winter. The installation was made under emergency conditions on a very heavily traveled highway and the work of laying the cable was designed so as to produce minimum delay or interference with resurfacing operations. The system was designed to dissipate 30-40 watts per square foot. The installation was a limited success due to dislodging of the cable.

   Installation Costs - $1.56 per square foot

   Heat Dissipation - 30-40 watts per square ft. per hour

2. An improved installation was constructed in 1964 on two ramps in the interchange of Routes 46 and 17 in Teterboro, Bergen County, N.J. Before the installation of heating cable, traffic was always considerably delayed during freezing storms.

The ramp from both northbound and southbound Route 17 converge into a single roadway which crosses a bridge over northbound Route 17 and then join eastbound Route 46. The ramp roadways are bituminous concrete and the bridge deck is reinforced concrete. The entire heated roadway is on a grade of 5.95 percent.

The system dissipates 35-40 watts per square foot of roadway. The cables are solid copper which is mineral insulated and copper jacketed.

For the three winters the roadway heating system has been in service it has performed satisfactorily, keeping the ramps relatively clear of snow and ice. There may be an accumulation of snow during heavy snow storms, however, this is soon melted. At no time has ice formed.

Installation Costs - $3.95 per square foot

Operating Costs - $.45 per square foot per year ?

Heat Dissipation - 35-40 watts per square ft. per hour

Oregon

An embedded pipe system using natural hot springs as a heat source was installed during the construction of a new north entrance to the City of Klamath Falls, Oregon, in 1950.

The snow melting system was necessitated by the fact that the proposed roadway would be constructed on an eight percent grade, thus producing a major traffic hazard when covered with ice or snow.

This installation is still operating today and results have been most satisfactory.

Installation Costs - $.90 per square foot

Operating Costs - $.05 per square ft. per year

Heat Dissipation - 45 BTU per hour per square ft.

Toronto, Canada

In 1961 a heating system using electric heating elements was installed in one of the on-ramps of the F. G. Gardiner Expressway in metropolitan Toronto for a length of 782 feet at a six percent grade and later in 995 feet of the off-ramp.

The on-off ramps presented a serious snow removal problem in that they required snow removal equipment to leave the Expressway. Once off the Expressway, this machinery has great difficulty getting back on again due to heavy and often snarled up traffic on the adjoining streets. This installation has proved very successful in melting snow and ice.

Installation Costs - $3.40 per square foot

Operating Costs - $.32 per square foot per winter

Heat Dissipation - 30-40 watts per square foot per hour